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辽宁西部早白垩世一新的有尾两栖类 (*Liaoxitriton zhongjiani*)[1)]

董枝明　　王　原

(中国科学院古脊椎动物与古人类研究所　北京　100044)

摘要　辽宁葫芦岛市九佛堂组发现一批有尾两栖类化石。经初步研究建立一新属种：钟健辽西螈 *Liaoxitriton zhongjiani* gen. et sp. nov.。辽西螈是东亚中生代有尾两栖类的首次发现，也是中国除早中中新世中新原螈外有尾两栖类化石的唯一报道。它代表一类小型的较原始的有尾两栖类。其头骨特征、犁骨齿列形态等与小鲵科的 *Batrachuperus* 比较相似。辽西螈的深入研究将对有尾两栖类的起源、早期演化，及其地理迁徙提供重要的信息。

关键词　辽宁西部，早白垩世，有尾两栖类

中图法分类号　Q915.863

1　前言

有尾两栖类(广义的蝾螈)是现生的三大类两栖动物中的一个重要门类(另外两大类是无足类和无尾类)。因为有尾类的形态特征与无足类和无尾类相比是较少特化的，更接近现代两栖类的祖先类型(如果认为现代两栖动物及其化石代表是一单系类群，如Duellman, 1988；Milner, 1988; Trueb and Cloutier, 1991a, b所主张)，所以早期有尾类化石的研究可以对探讨现代两栖类的起源、早期演化和迁徙提供重要的信息。现生有尾类共计有360—370种，分隶9科60余属(Duellman and Trueb, 1986), 主要分布于北半球(全北区)，仅少数种类渗入到热带。非洲(除西北角)、南美南部和大洋洲均不产之。

新生代有尾两栖类化石仅分布在北方大陆，以北美和欧洲发现较多；有尾两栖类化石在中生代十分稀少(Estes, 1981)。本文描述的辽宁蝾螈化石是中国中生代有尾两栖类的首次报道。此前我国仅报道过一种新生代的有尾两栖类：中新原螈 *Procynops miocenicus*, 产自山东临朐晚中新世山旺系(杨钟健，1965)。该地层的时代后来被修订为早中中新世(李传夔等，1984)。本文描述的蝾螈化石发现于辽宁葫芦岛市沙脚城，由阜新矿物局地质学家常征路先生采集并提供地质资料。化石产自九佛堂组灰黑色页岩中。九佛堂组的时代为早白垩世(郝诒纯等，1982；金帆，1996)。最近，在辽宁省西部和河北省北部的中中生代地层中也发现了一些重要的有尾两栖类化石，但目前还没有报道和描

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述。

本文描述的有尾两栖类化石保存在大小30多块页岩片上，代表20余个较完整或不完整的蝾螈个体。文中引用的有尾两栖类骨骼学名称主要依据 Duellman 和 Trueb (1986)和 Estes (1981)。

2 标本描述

两栖纲 Amphibia Linnaeus, 1758

滑体两栖亚纲 Lissamphibia Haeckel, 1866

有尾目 Caudata Scopoli, 1777

科未定 Family Incertae Sedis

辽西螈属(新属) *Liaoxitriton* gen. nov.

属型种 钟健辽西螈(新属、新种) *Liaoxitriton zhongjiani* gen. et sp. nov.。

包括种 仅有属型种。

词源 属名“辽西螈”根据化石产地在辽宁西部而命名；“Triton”是希腊词根，意义为水生的蝾螈。种名“钟健”献给我国蝾螈化石研究第一人杨钟健教授。

特征 小型纤细的蝾螈，吻臀距约为69 mm；骨架全长120—140 mm。头骨长略大于宽；头骨骨片表面无坑窝结构。前颌骨与上颌骨分别具齿约25和50枚；齿骨齿数超过70枚；齿均为基座型齿。犁骨齿列短小，远端伸向侧后方，两犁骨齿列之间不相连。舌器骨化。脊椎双凹型；骶前椎16个；脊椎横突长约为椎体长度的一半。肋骨单头，近端膨大。前肢四指，后肢五趾。

钟健辽西螈(新种) *Liaoxitriton zhongjiani* sp. nov.

(图1—5；图版I，II)

正型标本 一个关节在一起的骨架，头骨骨片残破，四肢保存不全。骨架从中裂开分粘在两块页岩上。中国科学院古脊椎动物与古人类研究所标本编号：IVPP V11582A 和 V11582B。

归入标本 总计33块编号的标本，包括保存完好程度不等的骨骼与印痕(编号 IVPP V11583—V11615)。

产地与层位 辽宁葫芦岛市沙脚城；下白垩统九佛堂组。

种征 同属征。

描述 正型标本是一关节在一起的骨架，骨架从中分开，粘在正反两片灰黑色页岩上。四肢保存不全，但头骨及脊柱保存了重要的鉴定特征，故将其列为正型。根据其完全的骨化判断，正型标本应代表一成年个体。骨架从吻端到尾端全长约120 mm。吻臀距(吻前端至腰带距离)约为69mm。如无特别说明，下面的描述依据正型标本。

头骨(图1)长21 mm，宽18 mm。吻部短而窄，但前端并不尖锐。吻端可见一对前颌骨，其上有约25枚牙齿。吻后部有一椭圆形的开孔，背腹面都可以观察到，其纵长约为2.5 mm。因标本残破，未观察到前颌骨的后突(又称鼻突)；根据前颌骨的形状及与相邻

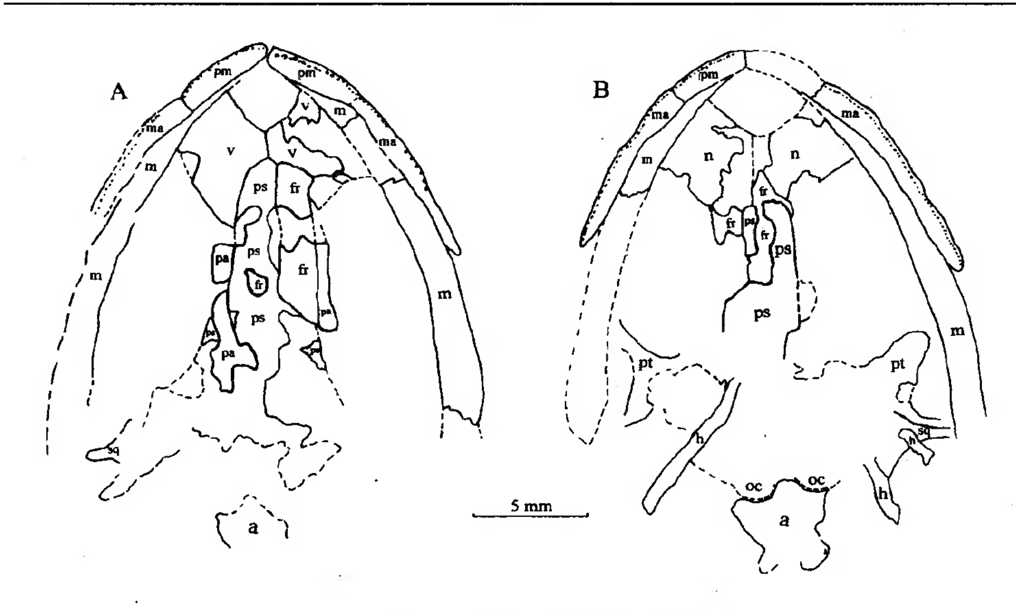


图 1　钟健辽西螈(新属、新种)

A．正型标本头骨 B 面视(V11582B)，鼻骨缺失(保存在 V11582A 上)，残破的额骨及顶骨显示背面，同时露出犁骨与副蝶骨的背面；B．正型标本头骨 A 面视(V11582A)，犁骨缺失(保存在 V11582B 上)，残破的副蝶骨显示腹面，同时露出鼻骨与额骨的腹面

Fig.1　*Liaoxitriton zhongjiani* gen. et sp. nov.

A: The skull of the type specimen in dorsal view (V11582B). Nasals are absent (preserved on the counterpart), also frontals and parietals are poorly preserved, showing part of the dorsal surfaces of vomers and parasphenoid. B: The skull of the type specimen in ventral view (V11582A). Vomers are absent (preserved on the counterpart), also parasphenoid is poorly preserved, showing part of the ventral surfaces of nasals and frontals. a, atlas; fr, frontal; h, hyobranchial skeleton; m, mandible; ma, maxilla; n, nasal; oc, occipital condyle; pa, parietal; pm, premaxilla; ps, parasphenoid; pt, pterygoid; sq, squamosal; v, vomer

骨片的关系判断，前颌骨很可能无后突或有一短的后突。上颌骨位于前颌骨的后侧方，与后者贴连。其上有大约 50 枚牙齿。上颌骨的后端逐渐变窄，向后侧方延伸至头长的一半。前颌骨齿与上颌骨齿均为基座型齿(pedicellate teeth)。

正型标本保存犁骨一对，位于前颌骨与上颌骨的内侧；尽管残破，但仍可分辨出其大致形状为菱形。在正型标本头骨的 B 面视中，由于鼻骨粘在另一模上，且额骨与顶骨残破，可以明显地见到两个犁骨的前部在中线处会合，副蝶骨插入到两个犁骨的中后部(图 1)。所有标本都没有显示出犁骨的腹面。根据犁骨腹面印模判断(V11587，图版 II-1)，犁骨齿列呈短的弧形，位于犁骨的中部，远端向后侧方延伸。两犁骨齿列在中央不会合。由于化石保存不好，无法肯定犁骨齿的形态、数目以及每个犁骨齿列的行数。V11599 号标本显示每个犁骨齿列可能由 1—2排犁骨齿组成。

副蝶骨位于颅底的中央，其前突的前缘可能为光滑的圆弧形，插入到两个犁骨的中后部；副蝶骨的后部在所有标本中都没有保存。因为所有化石的眼眶前部保存均不完整，所以无法确定前额骨与泪骨的存在。

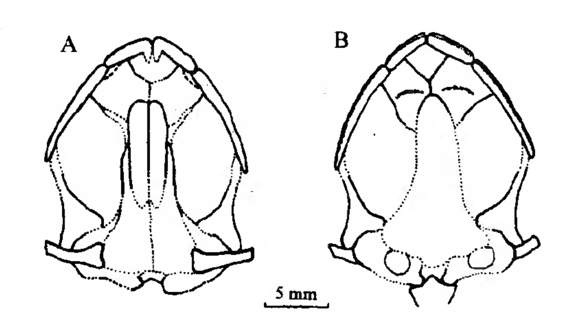


图2 钟健辽西螈(新属、新种)的头骨复原
A. 头骨背面视；B. 头骨腹面视，包括环椎，不包括下颌支与舌器

Fig.2 Reconstruction of the skull of *Liaoxitriton zhongjiani* gen. et sp. nov. in dorsal (A), and ventral (B) views. Atlas is showing in ventral view. Mandibles and hyobranchial skeleton are not included

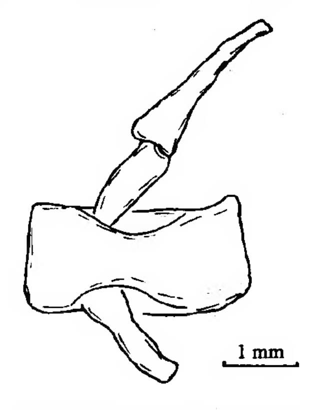


图3 钟健辽西螈(新属、新种) 正型标本(V11582A)第八骶前椎腹视，右侧肋骨缺失，示单关节头肋骨

Fig.3 *Liaoxitriton zhongjiani* gen. et sp.nov. Ventral view of the 8th presacral vertebra of the type specimen (V11582A), right rib is lost; a unicapitate left rib is showing

正型标本显示了一对大的椭圆形的眼眶，纵径约4 mm。无方轭骨(quadratojugal)。翼骨三叉形，前支伸向上颌骨的后端；根据V11598号标本的翼骨印痕判断，翼骨的前支可能贴连在上颌骨后端的内侧。翼骨的耳支(otic ramus)向后内方伸向耳囊(otic capsule)，后支伸向后外方，与鳞骨相连。正型标本的鳞骨保存不完整，根据V11592号及V11598号标本的补充，可以发现鳞骨大致呈微曲的棒状，近端膨大但无明显的分支，远端伸向外侧方，与翼骨的后支相连。

鼻骨保存不好，大致呈菱形。根据印痕判断，两鼻骨的前中部在中线处会合，中后部被额骨覆盖。额骨形状近似于一个长的矩形，两侧被顶骨包围。顶骨保存很破碎，但可以清楚地看出其前端向前延伸包围额骨的后外侧。以现有标本无法判断额顶囟孔的存在。所有标本的耳囊区均保存不好，在正型标本上仅能分辨出两个枕髁(occipital condyles)的印痕，可以看出枕髁突出于颅顶之外。V11600号标本保存了部分耳囊，耳囊的腹面中后部显示一个大的洞孔，判断为卵圆窗(fenestra ovalis)。

下颌支较厚，前端渐尖，约有70多枚牙齿。由于化石保存破碎，无法判断下颌支的组成。舌器(hyobranchial skeleton)骨化，至少包括两对鳃弓，但该结构保存极不完整。综合正型标本和其它标本的头骨特征，我们做出了一个钟健辽西螈的头骨复原图(图2)。

脊柱由16个骶前椎(第一个为环椎，其余15个为躯椎)、一个骶椎、及多于20个尾椎组成。所有脊椎为双凹型。环椎较大，其前端与头骨的两个枕髁相关节。环椎上无横突和肋骨。

躯椎15个，每个长约2.8 mm。椎体具光滑凸出的腹面，无椎体下脊(subcentral keel)。椎弓的背面可能有一低的髓棘。椎体的中部变窄，横突由此伸出并延向侧后方。每个横突的长度约是椎体长度的一半(图3；图版II-2)。

躯椎和骶椎上具有单关节头的肋骨。肋骨的长度稍长于横突。每个肋骨的近端扁平

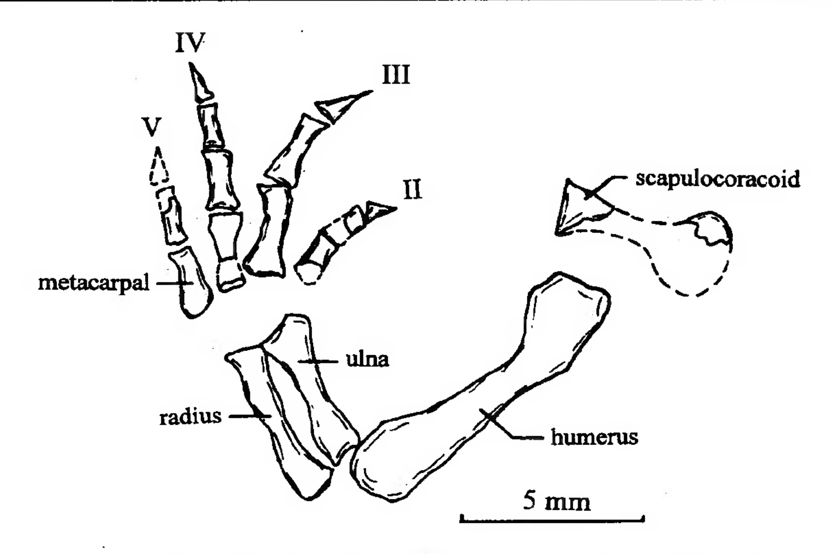


图 4　钟健辽西螈(新属、新种)　标本 V11583 的左前肢及肩带背视

Fig.4　*Liaoxitriton zhongjiani* gen. et sp. nov. Dorsal view of the left forelimb and pectoral girdle of specimen V11583. II–V, Digits II–V

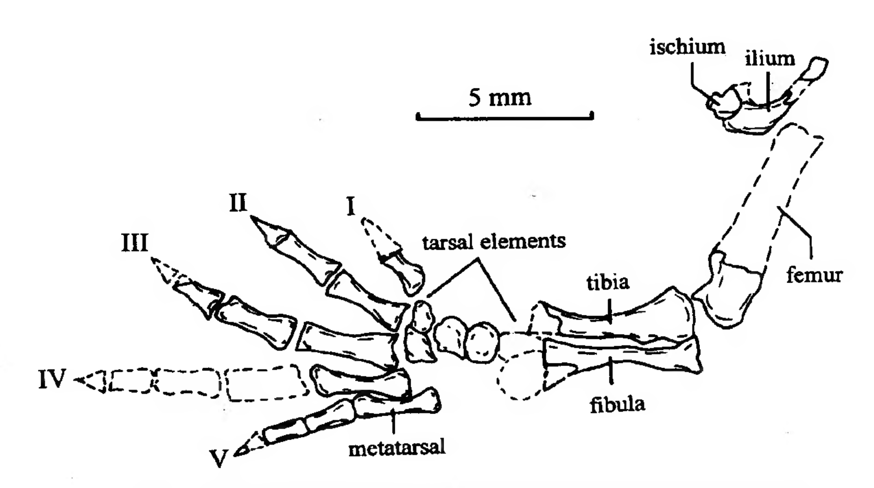


图 5　钟健辽西螈(新属、新种)　标本 V11584 的左后肢及腰带背视

Fig.5　*Liaoxitriton zhongjiani* gen. et sp. nov. Dorsal view of the left hind limb and pelvic girdle of specimen V11584. I–V, Digits I–V

膨大，与横突的远端相关节。尾椎从前向后大小逐渐变小，数目大于 20 枚，由于化石残破，无法确定具体的数目。V11591 和 V11612 号标本的前几枚尾椎保存有残破的肋骨或肋骨的印痕，判断约有 3—4 个骶后肋(postsacral ribs)。

正型标本没有保存肩带和前肢。V11583(图 4；图版 II-3)、V11598 和 V11600 号标本保存了残破的肩带及肩带的印痕。根据这些标本可以获知肩带由一块愈合的肩胛乌喙骨(scapulocoracoid)组成。该骨的近端膨大，远端伸长。骨片前缘无明显的凹刻(notch)。V11583 号标本还保存了较完整的前肢骨骼：肱骨粗壮；尺骨与桡骨不愈合，二者长度相近，约为肱骨长度的五分之三；前肢具四指，指式是 2，2，3，2；未见骨化的腕骨。

正型标本的腰带和后肢骨骼保存残破。V11584(图 5; 图版 II-4)和 V11585 号标本可以补充一些腰带的特征。腰带有两个骨化的单元: 髂骨和坐骨,未见骨化的耻骨。髂骨短,呈扁棍状,近端膨大。坐骨为一小骨片,与髂骨的膨大端相关节。V11584 号标本还保存了较好的后肢骨骼: 胫骨与腓骨不愈合,二者长度相近,稍短于股骨; 后肢具五趾, 趾式为 1,2,3,4,3。V11589 号标本具有同样的趾式。但值得一提的是 V11585 号标本显示第 5 趾只有两块趾骨。至少部分跗骨是骨化的(图 5)。从已有的材料判断,腕骨不骨化,但这些材料可能代表幼年或年轻的个体。腕关节和踝关节的特征有待充实标本进行深入的研究。

一些标本保存了皮肤的印痕(如 V11614 保存了很好的躯干及尾部的皮肤腹面印痕)。在躯干部的皮肤腹面印痕上可以识别出小的瘤疣, 但无大的瘤粒。

3 比较与讨论

钟健辽西螈 *Liaoxitriton zhongjiani* 在身体结构上是个毫无疑问的滑体两栖亚纲、有尾两栖类的成员。它具有滑体两栖类的进步特征如: 开放的颞区,基座型齿,头骨骨片的减少(如后顶骨、后眶骨、颧骨、方骨、和上颞骨的缺失。参考 Estes, 1981 和 Trueb, 1993 的性状分析)。*Liaoxitriton zhongjiani* 具有一长尾; 尺骨与桡骨、胫骨与腓骨均不愈合; 方轭骨缺失。这些特征与无尾两栖类相区别。其短而直的肋骨明显区别于爬行类及古生代的迷齿两栖类。钟健辽西螈的原始特征表现为具有短的犁骨齿列(后文继续讨论)。

在本文之前中国仅有一例蝾螈化石, 即早中中新世山旺组的中新原螈 *Procynops miocenicus* (杨钟健, 1965; Sun *et al.*, 1992)。中新原螈是东亚发现的第一个有尾两栖类化石。杨钟健(1965)建立了这个新属种并把其归入了蝾螈科。从中新原螈仅有的三块标本看,没有足够的特征证实杨钟健(1965)所假设的它与东方蝾螈 *Cynops orientalis* 的相似性(Estes, 1981)。尽管中新原螈的标本比较残破,我们还是可以鉴别出它与 *Liaoxitriton* 的明显不同。中新原螈个体更小,具有小的眼眶; 头骨骨片的排列方式与脊椎的数目也明显不同于 *Liaoxitriton zhongjiani*。

Ivachnenko (1978)描述了一种更大的蝾螈: *Karaurus sharovi*。它产自南哈萨克斯坦的上侏罗统(地层时代后来被修订为中侏罗世, Evans 和 Milner, 1996)。*Karaurus* 是可以确定的最早的蝾螈化石记录,它是所有其它蝾螈类的姐妹群(Estes, 1981; Duellman and Trueb, 1986)。*Liaoxitriton* 的犁骨齿列排列方式与 *Karaurus* 十分相似。这反映了辽西螈的原始性(Estes, 1981; Trueb, 1993; 见性状分析)。*Karaurus* 的吻臀距为 120 mm,远大于辽西螈。*Liaoxitriton zhongjiani* 的头骨骨片不具有坑窝构造,方轭骨缺失; 头骨结构及脊椎骨数目也不同于 *Karaurus*。

最近一篇关于西班牙早白垩世一新蝾螈的文章值得进一步的讨论。Evans 和 Milner(1996)描述了一个小型的变态期后的蝾螈: *Valdotriton gracilis*, 并较全面地回顾了蝾螈化石的早期记录。*Valdotriton* 的个体比 *Liaoxitriton* 小(吻臀距约 40 mm)。二者的相似点包括: 具有短的犁骨齿列,顶骨在额骨的侧面向前侧方延伸,骶前椎数为 16 枚。*Liaoxitriton* 区别于 *Valdotriton* 的是: 鼻骨无缺凹,前颌骨鼻突短(如果存在),肋骨是单关节头。Evans 和 Milner(1996)还讨论了其它一些破碎的中生代中期的蝾螈化石,与辽西螈

均无相似之处。

即使不考虑辽西螈与现生蝾源种类之间的巨大的时间跨度，把辽西螈与现生蝾螈联系起来也是比较困难的。中国的有尾两栖动物分为三个科：大鲵科 Cryptobranchidae、小鲵科 Hynobiidae 和蝾螈科 Salamandridae。这些科级划分所依据的特征有些并不为辽西螈所保存(如卵囊的形态，前关节骨与隅骨的愈合关系等)。在骨骼学特征中，犁骨齿列的形态，头骨骨片的形态与排列方式是有尾两栖类的重要的划分依据。综合考虑这两个方面的特点，*Liaoxitriton zhongjiani* 与小鲵科更为相似。该科被认为是复系的，是较原始的土著亚洲现生蝾螈的集合，至今没有发现化石代表(Estes, 1981; Trueb, 1993; 四川省生物研究所两栖爬行动物研究室，1977；田婉淑，江耀明，1986；胡淑琴，赵尔宓等，1987)。详细的比较表明 *Liaoxitriton zhongjiani* 与小鲵科的任何种类都不相同，但 *Liaoxitriton* 与山溪鲵属 *Batrachuperus* 最为相似，它们都具有短的犁骨齿列及前伸的顶骨，然而二者头骨的其它特征也有差别(如在 *Batrachuperus* 中鼻骨与上颌骨是不相连的)。综合以上讨论，辽西螈与已知所有蝾螈均不相同，故建立这个新属。

由于化石材料保存不完善，以现有的认识我们不能把辽西螈归入任何已知的科内，更何况有些科有可能是复系的。在进行进一步的系统发育分析前，我们暂时用“科未定”来处理这个中国现知最早的有尾两栖类。尽管如此，辽西螈的发现将该类群的亚洲化石记录前推了约 1.1 亿年，并且对有尾两栖类的早期演化、在亚洲的分布及分异提供了重要的信息，对世界有尾两栖类的化石研究也提供了一个重要的素材。本文仅是一个初步性的工作，进一步的工作无疑将极大地推动我国中生代有尾两栖类的研究。

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A NEW URODELE (*LIAOXITRITON ZHONGJIANI* GEN. ET SP. NOV.) FROM THE EARLY CRETACEOUS OF WESTERN LIAONING PROVINCE, CHINA

DONG Zhiming WANG Yuan

(*Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences* Beijing 100044)

Key words western Liaoning Province, China, Early Cretaceous, urodele

Summary

The salamander fossils have been especially scarce in Mesozoic deposits (Estes, 1981). In China, there was only one reported fossil salamander, *Procynops miocenicus*, from the upper Miocene Shanwang Series in Shandong Province (Young, 1965). The age of Shanwang Series later was revised as early middle Miocene by Li *et al.*(1984). The herein described fossil salamander was found in Sajiaocheng, Huludao City, Liaoning Province, collected by geologist Mr. Chang Zhenglu from the Coal and Geological Bureau of Fuxin City. The collector provided the horizon of this salamander as Jiufotang Formation, which is accepted as Early Cretaceous in age (Hao *et al.*, 1982; Jin, 1996).

Some other fossil salamanders also have been found from the Mesozoic deposits in the western area of Liaoning Province and the northern area of Hebei Province, neither were reported nor described. This is the first described Mesozoic caudate amphibian in northeastern China. The herein described fossils are preserved on more than 30 slabs of shale, representing more than 20 individuals. The terminology of urodele osteology follows that of Duellman and Trueb (1986) and Estes (1978).

1 Systematic Paleontology

Class Amphibia Linnaeus, 1758

Subclass Lissamphibia Haeckel, 1866

Order Caudata Scopoli, 1777

Family Incertae Sedis

Genus *Liaoxitriton* gen. nov.

Type species *Liaoxitriton zhongjiani* sp. nov.

Included species Only type species.

Etymology The generic name is derived from Chinese Pinyin "Liaoxi", which means the western part of Liaoning Province, where the fossils were discovered. "Triton" (Gr.) means a kind of newt. The specific name is dedicated to Dr. Yang Zhongjian (C. C. Young), who was the first to study salamander fossils in China.

Diagnosis Small slender salamander approximately 69 mm snout–pelvic length; total length of skeleton 120— 140 mm. Skull slightly longer than wide, with no sculpture on bones. Premaxilla and maxilla with estimated 25 and 50 teeth, respectively; dentary with more than 70; teeth pedicellate. Two vomerine teeth rows short, with no medial connection; their distal ends extending posterolaterally. Hyobranchial skeleton ossified. Vertebrae amphicoelous; sixteen presacral vertebrae present; transverse processes of vertebra half–length of centrum. Ribs unicapitate, with expanded proximal end. Manus four digits; pes with five.

Liaoxitriton zhongjiani gen. et sp. nov.

(Figs. 1—5; pl. I, II)

Holotype An articulated skeleton, with poorly preserved skull bones and limb bones. The skeleton is split into two, and preserved on two slabs of shale. IVPP (Institute of Vertebrate Paleontology and Paleoanthropology) specimen number: V11582A and V11582B.

Referred specimens A total of 33 catalogued specimens with variously preserved skeletons and imprints (IVPP V11583—V11615).

Locality and horizon Sajiaocheng, Huludao City, Liaoning Province; Early Cretaceous, Jiufotang Formation.

Diagnosis As for the genus.

Description The typical specimen is an articulated skeleton split and preserved on two slabs of gray–black shale. The appendicular skeleton is incomplete. This specimen is selected as holotype because its skull and vertebral column preserve important characters that are useful in classification. The typical specimen represents an adult form judging from its fully ossified skeleton. The skeleton is approximately 120 mm

long from rostral tip to caudal end. The snout–pelvic length is about 69 mm. The following descriptions are based on type specimen if there is no further notice.

The skull is 21 mm long by 18 mm wide (Fig. 1). The rostrum is short and narrow; however, the rostral tip is not pointed. A pair of premaxillae is present at the rostral tip, with estimated 25 teeth on each pars dentalis. An oval opening situates behind the rostral tip; it is nearly 2.5 mm in longitudinal diameter. The presence of the pars dorsalis can not be determined due to the poor preservation condition. It should be small, if present, considering the shape of the premaxillae and adjacent bones. The maxilla abuts the premaxilla anteromedially, with approximately 50 teeth; it extends posterolaterally to the mid–length of the skull. Premaxillary and maxillary teeth are all pedicellate.

A pair of vomers is medial to the premaxillae and maxillae. In type specimen V11582B, the nasals are absent (preserved on the counterpart), and the frontals and parietals are poorly preserved, so the underlying vomers and parasphenoid are showing their dorsal surfaces. Although not well preserved, the vomers can be identified as diamond–shaped, and meet one another in the midline anterior to the parasphenoid. No specimen shows the ventral surface of the vomers; however, determined from the imprints (V11587, pl. II–1), vomerine teeth are arranged in a short curved row in the middle of each vomer. The distal end of each teeth row extends posterolaterally. Two vomerine teeth rows do not meet each other in the midline. Because the fossils are not well preserved in this area, the shape and number of vomerine teeth, and the number of lines of each teeth row can not be determined. Specimen V11599 shows that each vomerine teeth row may have 1—2 lines of denticles.

A parasphenoid is situated in the middle of the skull floor; its anterior end is round, and invests between the posterior parts of the vomers. The posterior portion of the parasphenoid is not preserved in all specimens. Because of poorly preserved anterior part of the orbits, the presence of the prefrontals and the lacrimals can not be determined from known specimens.

The orbits are large, oval–shaped, and approximately 4 mm long in diameter. No quadratojugals are present. The pterygoid is triradiate; its anterior ramus extends towards the posterior tip of the maxilla, but no trace of articulation of the pterygoid and the maxilla can be found. However, in specimen V11598, the imprints of the pterygoids show a possible connection between the two elements, with the anterior ramus of the pterygoid medial to the posterior end of the maxilla. The otic ramus of the pterygoid connects to the otic capsule, while the posterior ramus extends posterolaterally, and connects to the squamosal. On the type specimen, the squamosals are not preserved completely. Supplemented by specimens V11592 and V11598, the squamosals can be determined as a curved rod in shape. They have an expanded

proximal end, and extend laterally to articulate to the posterior ramus of the pterygoids.

Nasals are not well preserved. They are approximately diamond-shaped. They meet each other in the midline anteriorly, and covered by the frontals posteromedially. The shape of each frontal is close to a rectangular. The frontals are surrounded posterolaterally by the anterior extension of the parietals. Preservation of the parietals is very fragmentary, though the anterior extension of each parietal can be identified clearly. The presence of the fontanels on the skull roof can not be determined by current specimens. The otic capsules are poorly preserved in all specimens. On the type specimen, only two imprints of occipital condyles can be identified, which extend beyond the skull roof. Specimen V11600 preserves part of the otic capsules, in which a large fenestra ovalis can be seen at the posterior middle on the ventral side of the otic capsules.

The mandibles are relatively thick, and taper at their anterior ends. There are more than 70 teeth estimated on each dentary. However, the composition of the mandible is not clear from current knowledge due to the fragmentary status of this element. The hyobranchial apparatus is ossified, with at least two ceratobranchials. However, detail of the structure of hyobranchial skeleton is unknown. Summarizing the cranial osteological characters of the type specimen and other specimens, a reconstruction figure is given here (Fig.2).

The vertebral column consists of 16 presacral vertebrae (the first of which is atlas; the rest 15 are trunk vertebrae), one sacrum, and more than 20 caudal vertebrae. All vertebrae are amphicoelous. The atlas is large. No transverse processes and ribs are present on the atlas.

There are 15 trunk vertebrae present; each is approximately 2.8 mm long. The centra have smooth convex ventral surface with no subcentral keel. A small neural spine is present probably on the dorsal surface of each vertebra. The vertebrae are narrowed in the middle, where the transverse processes come out and extend posterolaterally. Each transverse process is approximately half the length of the centrum (Fig.3; pl. II-2).

Unicapitate ribs are present on trunk vertebrae and sacrum. Each rib is slightly longer than the transverse process. The proximal end of each rib is expanded, and articulates with the distal end of the transverse process. The caudal vertebrae gradually decrease in size from anterior to posterior. There are more than 20 caudal vertebrae estimated. Specimens V11591 and V11612 have poorly preserved postsacral ribs or their imprints. According to these specimens, the first 3—4 caudal vertebrae have postsacral ribs.

The type specimen does not preserve pectoral girdle and forelimbs. Specimens V11583 (Fig.4; pl.II-3), V11598 and V11600 can fill in this blank. Determined from

these specimens, the pectoral girdle is composed of only one bone, the scapulocoracoid. It is expanded proximally, and elongated distally. There is no obvious notch at the anteromedial margin of the girdle. Specimen V11583 also preserves relatively complete forelimb skeleton. The radius and the ulna are separate, and of similar size; both are 3 / 5 the length of the humerus. There are four digits on the manus; the phalangeal formula is 2,2,3,2. No ossified carpal elements can be seen in all specimens.

The pelvic girdle and hind limbs are poorly preserved in type specimen. Specimens V11584 (Fig. 5; pl. II–4) and V11585 can give more information on these structures. Two ossified elements, the ilium and the ischium, are present on the pelvic girdle. The ilium is short, compressed stick–shaped, and proximally expanded. The ischium is a small piece of bone, articulating to the expanded end of the ilium. Specimen V11584 also preserves relatively complete hind limb skeleton, with separated tibia and fibula, which are slightly shorter than the femur. Each pes has five digits; the phalangeal formula of the pes is 1,2,3,4,3; this formula is shared by specimen V11589. However, an exception is found in specimen V11585 where the 5th digit has only two phalanges. At least part of the tarsal elements is ossified, whereas the carpal elements are not ossified determined from current specimens. For the latter situation, it may be from larval or juvenile individuals.

Some specimens preserve skin impression (e.g., V11614 has well–preserved ventral skin impression). Small tubercles can be recognized on the ventral skin impression. But no large tubercles are visible.

2 Comparison and discussion

Liaoxitriton zhongjiani is clearly a urodele and lissamphibian generally in structure, especially in the derived features of open temporal area and lack of many cranial bones (e.g., the lost of postparietals, postorbitals, jugals, tabulars, and supratemporals. Estes, 1981; Trueb, 1993). It has a long tail; the radius and the ulna are separate, so are the tibia and the fibula; the quadratojugals are absent (different from anurans). The vertebrae of this animal have short, straight ribs (different from reptiles). This animal is primitive in having short, posterolaterally extended vomerine teeth rows. It was the first Mesozoic fossil salamander reported in China.

There was only one fossil salamander in China before this paper, *Procynops miocenicus* from the middle Miocene Shanwang Series (Young, 1965; Sun *et al.*, 1992). It was the first urodele fossil found in East Asia, and was assigned to the family of Salamandridae (Young, 1965; Estes, 1981). The only three specimens of *Procynops* did not give adequate information to confirm their similarities to *Cynops orientalis* supposed by Young (1965). However, comparing with Young's description, we can still be sure that *Liaoxitriton* is quite different from *Procynops*. *Procynops* is

a smaller salamander, with small orbits. The arrangement of skull bones and the number of vertebrae of the two taxa are also different.

Ivachnenko (1978) described a larger fossil salamander, *Karaurus sharovi*, from the Upper Jurassic in southern Kazakhstan (the age later was revised as Middle Jurassic). It was the earliest record of definitive fossil salamander, and was treated as the sister group of all other urodele taxa (Estes, 1981; Duellman and Trueb, 1986). The arrangement of vomerine teeth rows of *Liaoxitriton zhongjiani* is very similar to that of *Karaurus*. This may represent the primitive feature of this animal (Estes, 1981; Trueb, 1993; see character analysis). *Karaurus* has a snout-pelvic length of 120 mm, much greater than that of *Liaoxitriton*. *Liaoxitriton zhongjiani* does not have heavily sculptured dermal bones, and also no quadratojugals are present. The skull structure and vertebrae number of *Liaoxitriton zhongjiani* are also different from those of the Jurassic salamander.

A recent paper on a new salamander from the Early Cretaceous of Spain deserves further notice. Evans and Milner (1996) described a small metamorphosed salamander, *Valdotriton gracilis*, and gave a relatively comprehensive review of the early fossil records of salamanders. They also evaluated different cladograms of salamander family interrelationships, and provided one for their new genus. *Liaoxitriton zhongjiani* is similar to *Valdotriton* in having short vomerine teeth rows, anterolateral extensions of the parietals lateral to the frontals, and 16 presacral vertebrae; but it is different from this Spanish genus in having non-notched nasals, short (if present) alary processes of premaxilla, and distinct unicapitate ribs. *Liaoxitriton* is also different from all other mid-Mesozoic salamanders as discussed in Evans and Milner's paper.

It is not likely to associate *Liaoxitriton zhongjiani* to the living taxa of salamanders. There are three families of living salamanders in China: Cryptobranchidae, Hynobiidae, and Salamandridae. These families are diagnosed by some characters that *Liaoxitriton* does not preserve (e.g. egg clutch, status of prearticular and angular, etc.). The shape and arrangement of cranial bones and those of the vomerine teeth rows are two important osteological characters in the classification of caudate amphibians. Considering these two features, *Liaoxitriton zhongjiani* is more similar to Hynobiidae, a family with only recent Asian distribution, than to the other two families. However, *Liaoxitriton* is different from any living taxa in detailed comparison (Division of Herpetology of Sichuan Biological Institute, 1977; Tian and Jiang, 1986; Hu and Zhao *et al.*, 1987). In Hynobiidae, *Liaoxitriton* is most similar to *Batrachuperus* in the presence of two short vomerine teeth rows, but different from the latter in other cranial bone characters (e. g., the nasals are not connected to the maxillae in *Batrachuperus*).

Current knowledge on this urodele can not justify a family arrangement because of

inadequate information from the specimens. We temporarily use "family uncertain" to treat this earliest known Chinese salamander taxon. However, the discovery of this urodele not only has extended the Asian record of this group by some 110 million years, but also has shed light on the early evolution, distribution, and diversity of salamanders in Asia, as well as in the world. This is only a preliminary work. Further studies will provide a better understanding of this animal.

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图版说明 (Explanations of plates)

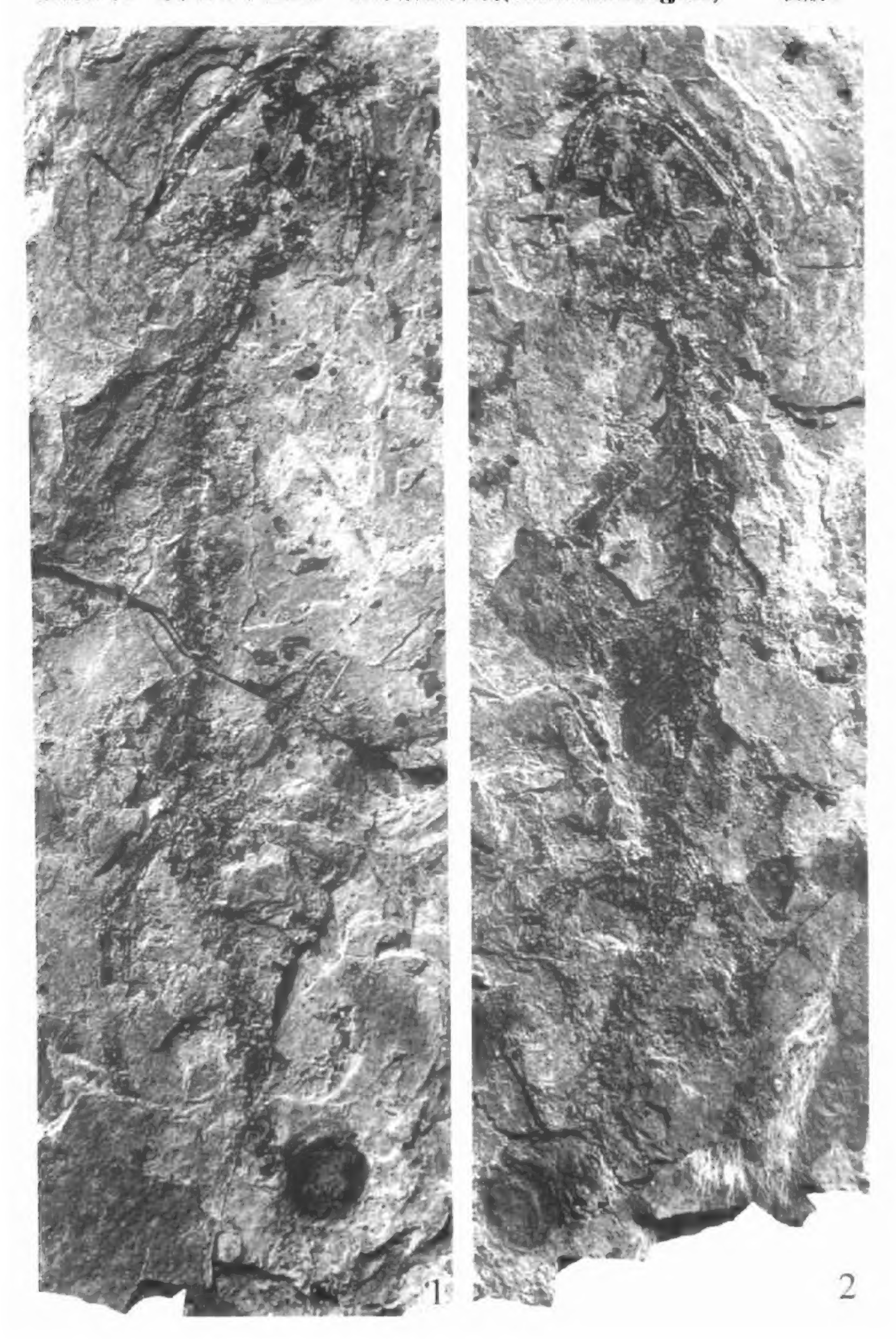
图版 I (Plate I)

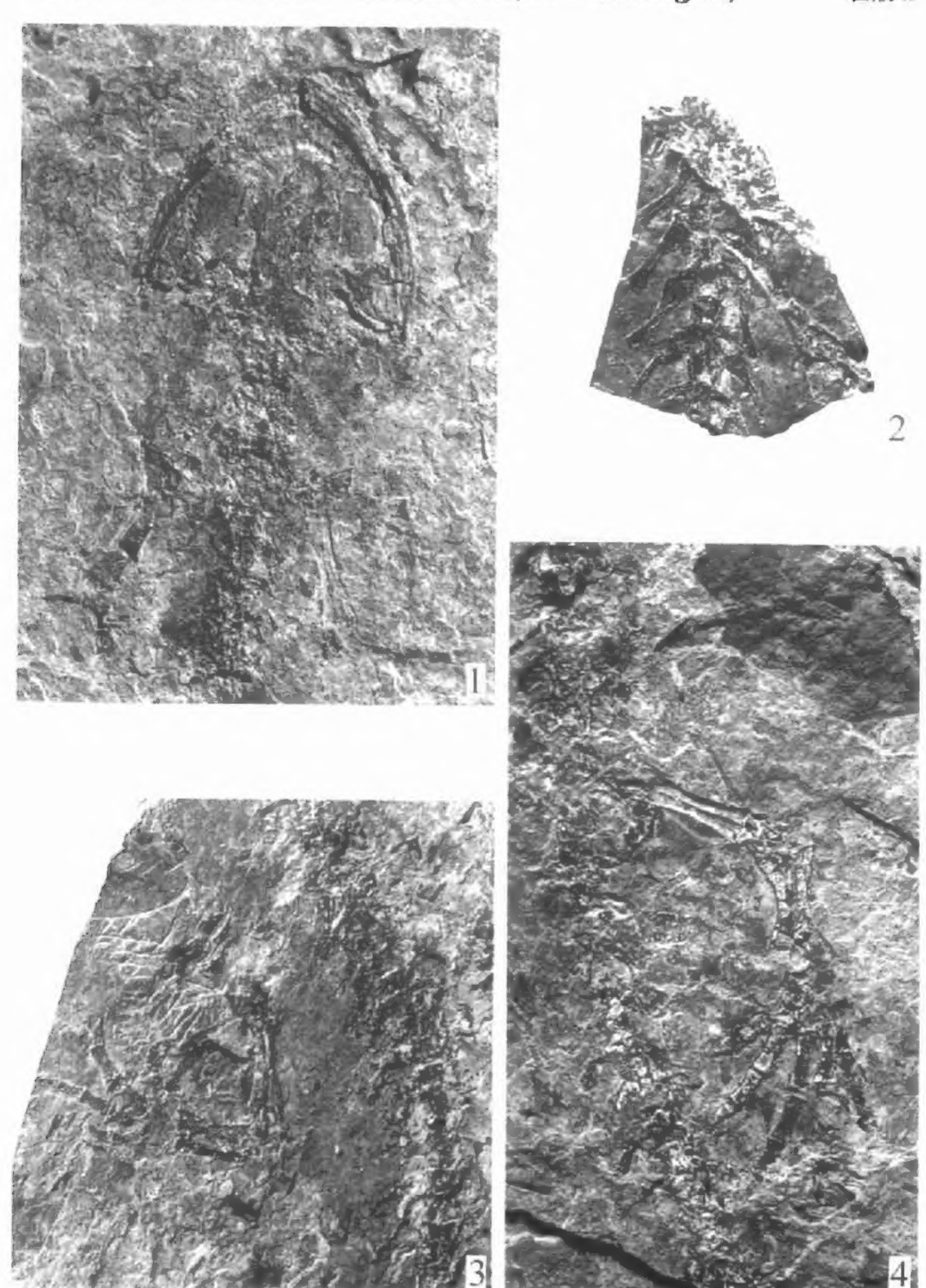
钟健辽西螈(新属、新种) (*Liaoxitriton zhongjiani* gen. et sp. nov.), 正型标本(holotype), ×2
1. 背视(dorsal view), V11582B; 2. 腹视(ventral view), V11582A

图版 II (Plate II)

钟健辽西螈(新属、新种) (*Liaoxitriton zhongjiani* gen. et sp. nov.), ×3

1. 头骨背视(skull in dorsal view), 示犁骨齿列印痕(showing imprints of vomerine teeth rows); V11587
2. 脊柱一段, 骶前椎(part of vertebral column, presacrals), V11586
3. 左前肢与肩带(left forelimb and pectoral girdle), V11583
4. 左后肢与腰带(left hind limb and pelvic girdle), V11584


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